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Master's thesis

The association between the White Line Atlas Method and claw horn disruption lesion prevalence compared to the Danish Method - a repeated cross-sectional study with validation of six Danish claw trimmers

Andreas Hvirgel Moesgaard Jensen & Ole Stærk Nicolajsen

Advisor: Nynne Capion, DVM, PhD, Associate Professor
Co-Advisor: Mogens A. Krogh, DVM, PhD, Researcher

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Faculty:	Faculty of Health and Medical Sciences
Department:	Department for Veterinary Clinical Sciences
Authors:	Andreas Hvirgel Moesgaard Jensen (LQZ812)
	Ole Stærk Nicolajsen (GVM814)
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Advisor:	Nynne Capion, DVM, PhD, Associate Professor at University of Copenhagen
Co-advisor:	Mogens A. Krogh, DVM, PhD, Researcher at Aarhus University
Date:	January 3, 2022

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Andreas Hvirgel Moesgaard Jensen (LQZ812) Date

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Ole Stærk Nicolajsen (GVM814) Date

Abbreviations

BOP	Break over point
CHDL	Claw horn disruption lesion
CI	Confidence interval
DAM	Danish Method
DS	Double sole
HTA	Hoof Trimmers Association
κ	Cohen's kappa
OR	Odds ratio
P3	Distal phalangeal bone
SH	Sole Hemorrhage
WLA	White line abscess
WLAM	White Line Atlas Method
WLF	White line fissure

Preface

This project was performed in the autumn of 2021 and corresponds to 30 ECTS points, as a final part of our master's degree. The theme of this Master's thesis was inspired by ”Klovens år”, an initiative from the Danish Veterinary Association to increase focus on claw health throughout 2021. The authors hope this paper can contribute to the improved claw health in Danish dairy herds.

The authors would like to thank our advisor, Nynne Capion, for invaluable sparring and enlightenment in the design, creation, and completion of the project along with invitations to seminars and trimming courses. Our co-advisor Mogens A. Krogh also deserves our deepest appreciation for his tireless and thorough guidance in the world of data handling, biostatistics, and interpretation of results. We are also extremely grateful towards the 6 claw trimmers whom, hardly informed about the cause, let us disturb their work and judge their livelihood without ever breaking a sweat. The authors were astonished and grateful for their hospitality and enthusiasm towards the profession. In the same breath, we would like to show our gratitude towards Canadian claw trimmer, Victor Daniel for proofreading and answering all our questions about the correct interpretation of the White Line Atlas Method. To our fellow students, we are forever thankful for your support, and finally, we are extremely grateful to the fiancée, family, and friends who endured our company during this endeavor.

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Abstract

Claw horn disruption lesions (CHDL's) are a frequent problem in modern dairy herds and the method used for preventive claw trimming is hypothesized to have an effect on the prevalence of these lesions. Therefore we choose to validate the claw health recording practice and claw trimming technique of 6 selected, educated, Danish claw trimmers, by assessing discrepancies with the principles of the White Line Atlas method (WLAM) and comparing recordings with a golden standard. The validation of compliance to the method was evaluated on 5 parameters on the hind legs, while the validation of recording was done comparing the trimmers recordings to the findings of the authors. This was compared with an analysis of the association of the WLAM on the prevalence of CHDL's, compared to the Danish method (DAM) of claw trimming. The 6 claw trimmers were selected based on a change of method from the DAM to the WLAM, resulting in 2 study periods of 2 years each. A repeated cross-sectional study was performed analyzing claw health records from 29 farms using a general linear mixed effect model, with leave-one-out cross-validation. The model reveals that the WLAM can be associated with reduced odds of sole hemorrhage (SH), sole ulcer (SU), white line fissure (WLF), and white line abscess (WLA) and increased odds for double sole (DS), but WLF and DS must be interpreted with caution qua unacceptable levels of agreement between the recordings of the trimmers and authors. A link between the trimmer's compliance to the WLAM and the effect of the method is found. Furthermore a large difference between the claw trimmers recording practice, compliance, and effect of the method was found. This indicates that not only the method, but also the trimmer's compliance influences the prevalence of claw horn disruption lesions. Based on the findings in this study, the Danish claw trimmers could reduce the prevalence of SH, SU, and WLA by adapting and complying to the WLAM.

1 Introduction

Claw lesions can be separated into skin-related and claw-horn-related, the latter, also termed claw horn disruption lesions (CHDL's) which include sole hemorrhage (SH), sole ulcer (SU), white line fissure (WLF), white line abscess (WLA), and double sole (DS). CHDL's in dairy cows are an important and frequent source of economic loss and reduced animal welfare in industrialized dairy production (Shearer et al., 2015). A significant part of lameness incidence originates from the claw (Shearer et al., 2015), and it has been found that around 70% of dairy cows in free-stall systems are affected by claw health lesions

(Manske et al., 2002a, Sogstad et al., 2005, van der Linde et al., 2010).

Beside the effect on animal welfare (Bruijnis et al., 2011, Stoddard and Cramer, 2017, Alvergnas et al., 2019) and production (Krpálková et al., 2019), claw lesions impact the economy of the farm as well. This impact has been found to vary between different types of lesions (Charfeddine and Pérez-Cabal, 2017). Under Danish conditions, Ettema and Østergaard (2006) found an average loss of 192 euros per first time lameness and in the Netherlands Bruijnis et al. (2010) suggests that 32% of the total costs of claw lesions come from subclinical cases.

The impact of lameness and CHDL's on economy and welfare should be a good motivator for farmers to focus on claw health, but the complexity of the subject often conceal the economic advantage (Anneberg et al., 2016). According to Charfeddine and Pérez-Cabal (2017) 43-60% of the cost of lameness comes from loss in milk production and early culling, while 10-20% of the cost is caused by reduced reproductive efficiency, and Omontese et al. (2020) finds that cows with claw lesions present at 20 days in milk have reduced odds of becoming cyclic. These are all factors difficult for farmers to correlate to claw health, but constitutes significant losses in welfare and economy. Therefore farmers may have some skepticism towards the multifactorial calculations showing a potential economic advantage in the future, as they might fear the many different interactions will equalize the economic advantage of an intervention (Anneberg et al., 2016). Providing more knowledge about claw trimming and prevention of CHDL's can help trimmers and veterinarians in their communication and assistance to the farmers. For herds which practice preventive claw trimming, this already thorough examination of the animals would be an ideal point of optimization and further collection of knowledge.

Different variations in trimming technique have been investigated since Toussaint Raven (1985) introduced the "functional method" as the first technique focusing on prevention as well as curing claw lesions. He recommended regular and routinely performed claw trimming of perceived healthy cows to avoid future lesions. This is today defined as preventive claw trimming. Toussaint Raven (1985) describes how the medial claws on the front legs and lateral claws on the hind legs become overgrown from increased load-bearing. The overload causes swelling of the corium with secondary hypertrophy of the claw capsule. This effect is magnified by the modern housing of dairy cows, but anatomical differences in the metacarpals and -tarsals along with weight-bearing differences is a probable cause to the difference in growth (Nacambo et al., 2007, Muggli et al., 2016, Nuss et al., 2019). Because variation is seen in which of the paired claws become overgrown between the front and hind legs but also between individuals, White and Daniel (2017) used the term ”stress claw” to describe the overgrown claw. This helps communication as this claw needs the most aggressive trimming no matter if it is lateral or medial, and ”stabilizer claw” describes the minor claw which needs less trimming. Archer et al. (2015) further investigated the anatomical structures of the claws and found the ideal toe length of Holsteins to be 90 mm, which is more than the 75 mm recommended by Toussaint Raven (1985). Because of these additions to the existing knowledge, the functional method has over time been slightly broadened and renamed to the Dutch 5 Step Method. Other techniques such as the Kansas adaptation of the Dutch Method (Siebert and Eureka, 2005), the White Line Method (Blowey, 2015), the White Line Atlas Method (WLAM) (White and Daniel, 2017), and the Danish Method (DAM) (”Kompendium for klovbeskærer 2018” N. Capion, 2018[1]) has been introduced and some of the most common are presented in Table 1.

Table 1: Summary of claw trimming methods

Dutch 5 Step	**White Line Atlas**	**Danish Method**
• Trim the stabilizer claw to a toe length of 75-90 mm • Trim the stress claw to match the stabilizer claw • Modelling of the sole • Curative trimming, removing the dead horn • Treatments if needed **Kansas adaptation** • Sole is trimmed to slope 3-4° towards the axial groove making the axial wall slightly shorter than the abaxial	• Evaluate stance and gait • Routine, salvage, or training trim • Recognize heel fulcrum and trim stress claw • Repeat for stabilizer claw • Trim toe length • Evaluate and trim sole thickness • Re-asses heel height and toe length. • Modelling of the sole	• Toe angle adjusted to 45-52° • Toe axis aligned with sagittal plane of the cow • Heel height aligned between lateral and medial claw • Sole thickness adjusted to 8-10 mm • Modelling of the sole

Even though all methods have been around for several years there is a lack of scientific evaluations and comparisons of their efficacy in the prevention of lesions and practical use. Manske et al. (2002a), Gomez et al. (2013), and Stoddard (2018) have, among others, executed controlled trials on the efficacy of claw trimming on preventing claw lesions and lameness. They all find claw trimming to be protective against lameness or lesions but they all used different adaptations of the Dutch 5 step Method: A focus on

[1]University of Copenhagen, Copenhagen, Denmark, nyc@sund.ku.dk

claw angle instead of claw length for Manske et al. (2002a), and more excessively modeling, on the stress claw alone, at the common sole ulcer site (where the flexor process of the pedal bone (P3) pushes against the sole) for Gomez et al. (2013) and Stoddard (2018). This makes the Dutch 5 step method the most thoroughly described while the other remains sparingly described in the literature. A yet unpublished masters thesis by Cannings (2021) has found one claw trimmers use of the WLAM in 4 selected herds in Denmark to reduce the prevalence of SH, SU, and WLF compared to the DAM.

Van Der Tol et al. (2004) who investigate weight-bearing and force distribution of claws trimmed with the Dutch 5 Step method find an increase in claw-surface contact area along with a decrease in average pressure in the hind legs after trimming, but the trimming fails to reduce maximum pressure. Van Der Tol et al. (2004) hypothesized that the maximum pressure along with the point of highest intensity is more important than the average pressure in developing CHDL's. Therefore it is important to move the point of maximum pressure to the strongest parts of the claw: the claw capsule, preferably zone 2, referred to as the ”pressure ridge” in the WLAM (White and Daniel, 2017).

Different authors have summarised the available knowledge on claw trimming in recent years. Shearer et al. (2015), Stoddard and Cramer (2017) Alvergnas et al. (2019), Sadiq et al. (2020), and Vidmar et al. (2021) have all made reviews of the literature regarding claw trimming and all agree on the theory that preventive claw trimming might well be essential in treating and preventing claw lesions, but also find a lack of scientific publications on the subject.

Detailed and consistent claw recordings from the claw trimmers can be an important tool and the first step to acknowledge: Which claw lesions are most frequent, if prevalence change, where the biggest improvements can be found, and to monitor the efficacy of interventions. Digital claw health recordings has been available in Denmark since 2009 provided as a freeware program by The Danish Cattle Association, SEGES. In the beginning only a few farmers and trimmers choose to use the program but the number has been increasing since. In 2020 approximately 49% of the Danish dairy herds recorded claw health at trimming[2]. Data collection by claw trimmers seem to have a large inter-observer variance between the different trimmers (Capion et al., 2021).

Routine claw trimming by professional claw trimmers has been practiced for many years in Den-

[2]See: https://www.landbrugsinfo.dk/public/e/3/a/sundhed_velfard_klovregistrering_sikrer_fokus (Accessed on: 17/12-2021)

mark. There is a formal education, but no official requirements or authorization exist for practicing as a claw trimmer in Denmark, but some trimmers use the term ”Examined claw trimmer” to display their education. The trimming technique in the claw trimmers curriculum has changed over the years. The most recent major change occurred in late 2018 when the DAM was replaced with the WLAM, but all trimmers are still free to choose which method they prefer.

The individual trimmers compliance to the method they claim to use has not yet been investigated. Personal observations and communication with expert and teacher at the Danish claw trimmer education, N. Capion, reveals a large discrepancy between the individual trimmers interpretation of the method used. Therefore it is important to assess the individual trimmers technique compared to the written method. Accordingly, we would like to validate a selected group of 6 claw trimmers use of claw health recordings and compliance to the principles of the WLAM by evaluating their trimming technique and recording practice. The trimmers have all changed from the DAM to the WLAM within the last 4 years creating the opportunity to do a repeated cross-sectional study investigating whether trimming with the WLAM compared to the DAM changes the odds of CHDL's.

The scope of this study is to illuminate the association of the method used for preventive claw trimming and the prevalence of CHDL's. Preventive claw trimming seems to have the potential to improve both animal health and welfare along with the economy of the dairy farmer, but it seems the ideal trimming method is still to be described. To reduce this paucity in knowledge concerning claw trimming methods, the first objective of the study is to validate the compliance of the 6 selected claw trimmers to the WLAM and the agreement of their claw health recordings to a golden standard. This is done to account for the variation between the claw trimmers in both trimming and recording. The second objective is analysis of claw recordings from 29 herds that uses the 6 selected claw trimmers to investigate the association between trimming method and CHDL prevalence.

2 Methods and materials

Among the 73 registered Danish claw trimmers[3], 6 Danish full-time claw trimmers were selected. 1 claw trimmer operates on Zealand and 5 trimmers operates in different parts of Jutland. 2 inclusion criteria

[3] See: https://www.kloven.dk/medlemmer.html (Accessed on 17/12 2021)

for trimmers was selected: I) A change in trimming method from the DAM to the WLAM when the new technique was introduced in 2018-19 and II) information from the Danish Cattle Association, SEGES, showing that these trimmers make recordings for mild SH, which is a rare practice among Danish claw trimmers (Capion et al., 2021).

The authors cherish a precise and concise dialog about trimming and claw lesions and thus appreciate the possibility to use the work of Greenough and Vermunt (1994). They developed a separation of the claw into 9 zones which was later modified by Shearer et al. (2002), Zinpro Performance Minerals and The International Lameness Committee[4] to also contain zones appointed 0, 10, 11, and 12, dividing a single claw into 13 different zones as seen in figure 1.

For all statistics calculations R version 4.0.3 (10/10 2020) (R Core Team, 2019) was used.

2.1 Trimming methods

The two claw trimming methods investigated in this study is described here in detail:

The Danish Method

The DAM is a modification of older trimming techniques used in Denmark and it primarily focuses on adjusting the toe angle to a recommended angle of 45-52°. The general principles of the DAM are (From ”Kompendium for klovbeskærer 2018” N. Capion, 2018[5]):

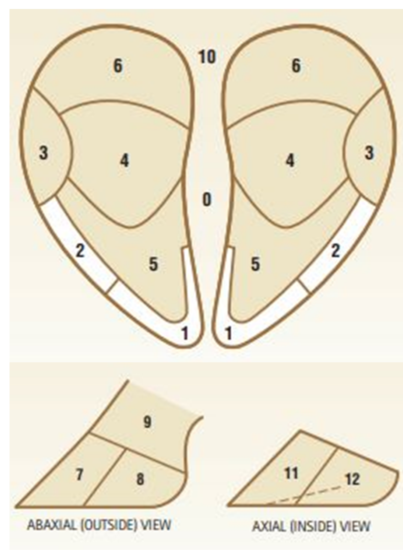

Figure 1: *Claw zones reproduced from ”Claw lesion identification in dairy cattle”, Zinpro Performance Minerals and The International Lameness Committee, 2008[4]*

1. Toe angle adjusted to 45-52° by trimming zone 1-5
2. Toe axis aligned with sagittal plane of the cow
3. Heel height aligned between lateral and medial claw
4. Sole thickness adjusted to 8-10 mm
5. Modelling of the common sole ulcer site

[4]See: ”https://www.zinpro.com/wp-content/uploads/2020/12/Claw-Lesion-Identification-in-Dairy-Cattle_INT-D40-08-30-07.pdf (Accessed 17/12 2021)

[5]University of Copenhagen, Copenhagen, Denmark, nyc@ku.dk

The White Line Atlas Method

In the 1960’s claw trimmers started adapting techniques from farriers which continued until Toussaint Raven (1985) made cattle-specific recommendations. Trimming was mainly evaluated by the final output instead of anatomical landmarks, and the goal of the trim was just to remove overgrown horn (White and Daniel, 2017). In 2012 the Board of the Hoof Trimmers Association (HTA) recognized the need for a common description of trimming methods and thus created the Trimmers Toolbox. Canadian trimmer Victor Daniel, who at the time was on the Board of the HTA and was acting Chair of the Education Committee for the HTA, was part of the decision to create 3 different cattle trimming methods for trimmers to consider: The Dutch 5 Step method, the Kansas adaptation, and the WLAM. The last method was developed by Victor Daniel together with the equine farrier Randall White, where the latter contributes with an increased focus and thus more complete knowledge of the balance and movement of the whole animal. Together they describe the balance in connection with how the claws and legs work in conjunction with the animal as a whole. They do not claim to have developed a new trimming method, but rather a new scientific explanation on how trimmers can use biomarkers to understand how the bovine foot can be trimmed to its best self-regulating profile. ”The animal is the evidence, not the method” is how the inventors describe the driving force behind their technique. The goal of the method is to create not only a pain-free and anatomical correct gait and stance, but also to mitigate natural wear of the claw horn reducing the need for preventive trimming, as modern housing of dairy cows often leads to unnatural claw horn growth versus wear rates, creating this need for preventive trimming (Somers et al., 2005, Telezhenko et al., 2009, van Amstel et al., 2016).

Using the WLAM, the trimmer needs to decide before the trim begins, whether the specific cow needs a routine, salvage, or training trim. The routine trim is chosen for cows with no or minor claw deformities and lesions, while salvage trimming is used for cows with deformities or lesions creating a need for correction of the conformation or reducing lameness. The training trim is rarely used as the goal of this trimming type is to conform with regulations and standards of breeding shows.

White and Daniel (2017) described 5 biomarkers and their use in trimming according to the WLAM:

1. **Heel fulcrum** - the heel fulcrum is found, on the stabilizer claw, between zone 2 and 3 and transfers to the stress claw following the transverse plane. The heel fulcrum should be perpendicular to the floor at the point of attachment of the common digital extensor tendon on the P3 on the front legs and at the point where the common digital extensor tendon splits in two on the hind legs.

2. **White line** - the white line is a vulnerable structure of the claw, connecting the soft horn of the sole with the hard wall horn. It should be sound and uniform, level with outer walls and it is important to recognize this structure for later trimming decisions.

3. **Sole thickness** - the sole thickness should be continuously evaluated throughout the trim and it is important to leave as much horn on the sole as possible. The normal sole thickness is found where the sole horn is newly formed and trimmers may look at the nature of the horn, as newly formed sole horn is moist, soft, and shiny while the old horn is dry, hard, and often white and crumbly.

4. **Pressure Ridge** - the pressure ridge is the part of the abaxial wall which carries most of the weight and it is defined as the abaxial wall where it follows zone 7 down to zone 2 and it should always be trimmed to have full contact with the floor.

5. **Break over point (BOP)** - the BOP is determined as negative, neutral, or positive based on whether the claws have natural wear in the toe. Positive indicates no need for toe trimming, neutral indicates need for shortening the toe by trimming the sole in zone 1 and negative indicates a need for trimming both sole surface and length of the toes.

After becoming familiar with the 5 biomarkers of the claw the trimmer should follow this course of action when trimming according to the WLAM (White and Daniel, 2017):

1. Evaluate the animal's stance and gait.
2. Trimming decision - routine, salvage, or training trim.
3. Recognize heel fulcrum on stabilizer claw, transfer to stress claw and trim the sole from fulcrum, through the pressure ridge, to toe until the white line can be recognized in zone 1 and 2.
4. Repeat the process for the stabilizer claw, refrain from trimming behind the heel fulcrum to avoid reducing sole thickness in the heel.
5. Trim the toe length on the stress claw just ahead of the BOP or up to $\frac{1}{3}$ of zone 1, to visualize the white lines in the toe which can then be used to determine how much sole horn can be removed. Repeat on the stabilizer claw.
6. Trim to normal sole thickness on the stress claw. From the heel fulcrum, through the pressure ridge, to the toe. Repeat on stabilizer claw if necessary, paying attention to only trimming from the heel fulcrum towards the toes.

7. Re-asses heel height and toe length. Heel height should only be adjusted by trimming the stress claw and only here trimming behind the heel fulcrum is allowed. Trim toe length according to BOP and visualization of claw zones and bevel the front of the toes to approximately 5° if the exposed surface is more than 7 mm.
8. Modeling of the sole surface, approximately the size of a tablespoon with $\frac{1}{3}$ on stabilizer claw and $\frac{2}{3}$ on the stress claw sloping towards the axial groove.

Step 1 ensures that each cow gets the trim it needs based on its variations in claw conformation, stance, and gait. Step 2 ensures that the trimmer is conscious of the goal of the trim. Step 3 is crucial to the WLAM, as it enables the cow to have a natural gait evolution with the step revolting around the center of the P3. It also helps establish a correct claw angle, preserves sole thickness in the heel, and last but not least it marks the caudal border of the trim on the stabilizer claw and therefore helps increase the heel height on the stabilizer claw. Step 4 helps visualize lesions and limits the area in which trimming is allowed. Step 5 makes the lateral and medial claw equal in length according to the natural wear of the specific claw ensuring a gait evolution perpendicular to the surface. This helps facilitate an even BOP and helps evaluate the sole thickness based on the white line where the claw wall meets the sole. Step 6 ensures that the trimmer evaluates the sole thickness before trimming to desired sole thickness. Step 7 ensures a good balance between lateral and medial claws along with ensuring good claw to floor contact and removing damaged horn. Furthermore, it ensures correct facilitation of the BOP after the correct sole thickness is obtained. Step 8 reduces the force exerted by the P3 flexor process on the corium of the sole. In the end, it should be noted that all evaluation and trimming should be done continuously and not one at a time.

2.2 Validation of trimming technique and recording practice

Claw trimming technique and claw health recordings were validated during 1 day on a single herd in the autumn of 2021 for each claw trimmer. The herds were commercial dairy herds, selection was based on the herds use of claw health recordings and at least 60 cows for routine trimming on the day of the validation. A herd were chosen according to these criteria by each claw trimmer. The validation consisted of observations of the trimming technique and subsequently the work of the claw trimmer was investigated further by interviewing and discussions with the trimmer regarding their technique. For their routine claw trimming, all trimmers used an upright hydraulic chute produced by the Danish company ”KVK Hydra Klov”, electrical angle grinders with 2-3 bladed knife discs, and classic hoof knives. Claw trimmer C and F had two chutes and therefore two teams of trimmers and this project focused on the chute with the main trimmer.

Claw health recordings and trimming technique were sought to be validated on alternating cows entering the chute, but cows with moderate to severe claw deformities (corkscrew claw, scissor claw, and chronic laminitis) on the hind claws were excluded from trimming validation and instead included in the validation of the claw health recordings. This had a greater impact in some herds as the prevalence of claw deformities varied between the herds, but in all herds, it was possible to achieve approximately the same amount of recording (n = 192 cows (25-38 per trimmer)) and trimming (n = 205 cows (29-37 per trimmer)) validations. Even though most of the trimmers used a different setup regarding the number of helpers and angle grinders, they all typed the lesions on a touchscreen as the other trimmers were yelling the lesions they discovered during or after the trim. The authors chose a more covert strategy in which codes (SH, SU, WLF, etc.) was used when communicating openly, and a more quiet communication via whispering was preferred, as to not interfere with the recordings made by the claw trimmers. Validation of the trimming technique was done exclusively on the hind legs because: These were more easily accessible, the prevalence of CHDL is higher (Somers and O’Grady, 2015) with a bigger need for prevention, and the authors assessed that trimming techniques used on the hind legs were in most cases also used on the front legs.

The interview of the claw trimmers was done using an unstructured interview format and to avoid interfering with the trimmer’s decisions it was performed during the last 5 trimmings of the validation.

The validation in this study caused no cows to be kept in the chute longer than 20 seconds more than required by the trimmer.

Validation of claw health recording

During the trim the two authors observed each side of the cow, following the flow of the trimmers, so that both the untrimmed claw, the trimming process, and the finished claw was observed as to not overlook lesions removed by the trimming process. No extra tools were used by the authors to clean or illuminate the claws. Claw deformities were examined by the authors on weight-bearing claws in the waiting stall right before entering the chute and then again on the lifted claw. Lesions were defined following the Nordic Claw Atlas[6] (updated in 2020) which also defines the recordings available to the trimmer. Recordings of mild and severe lesions were simplified to account for the presence of the lesion only. It is possible to do recordings on leg level, but since most of the trimmers explained how they avoided using the option of assigning leg levels to lesion recordings the analyses were performed on cow level. The authors have received training in recognizing claw lesions and have discussed the different lesions and how to recognize them with each other and with N. Capion to establish a golden standard and to eliminate intra- and interobserver variation. The authors used a dotting system on paper to record the lesions and on which leg it was located (see appendix A for data collection chart). All 6 trimmers used almost identical touchscreen setups with an online software delivered by the Danish Cattle Association, SEGES, logging the recordings in the Danish Dairy Management System. The recordings are property by the farmer and can be made available to researchers, farmers, veterinarians, and other interested parties. The trimmers recordings were extracted from the Danish Dairy Management System. The data for validation consists of herd ID and cow ID, parity, date of recording, lesion, and which legs were affected.

Cohen's kappa (κ) (Cohen, 1960) along with the percent agreement was used to assess the level of agreement between the authors and the claw trimmers. The percent agreement is included based on the theory presented by McHugh (2012) that percent agreement can yield better results when recordings have a small risk of being guesses, which is assumed to be the case for claw health recordings and experienced claw trimmers. Calculations were done per lesion for each claw trimmer. Acceptable levels of agreement were originally set by Jacob Cohen to a minimum of $\kappa = 0.41$, also called moderate agreement (McHugh, 2012). Thus acceptable levels of agreement are defined as: $\kappa = [0.41 : 0.60]$ moderate, $\kappa = [0.61 : 0.80]$ substantial, and $\kappa = [0.81 : 1.00]$ almost perfect agreement. For percent agreement, only levels above 61% will be regarded as acceptable with the same intervals as κ since this method generally yields higher results than κ values (McHugh, 2012).

[6]See: Nordisk klovatlas. https://www.landbrugsinfo.dk/-/media/landbrugsinfo/public/f/b/9/klovregistrering_nordisk_klovatlas _web.pdf (Accessed on 17/12 - 2021)

Validation of claw trimming technique

The trimming technique was validated using five parameters on the hind legs (Fig. 2) and the authors made sure to evaluate the claws for deformities before entering the chute to ensure that no lesion was overlooked because of differences in weight-bearing and non weight-bearing claws. The authors received training in the use of the WLAM by N. Capion to reduce the risk of intra- and interobserver variation. Before the trimming commenced the authors examined the BOP to establish an agreement on whether this particular claw needed trimming in the toe. Since not all claws need trimming at the toe, we chose this parameter to be evaluated based on the author's assessment of the BOP, given that a neutral or negative BOP needs trimming of the toe length while a positive BOP prohibits trimming of the toe length (Fig. 2 - yellow circle). Subsequently, the heel fulcrum (Fig. 2 - green circle), where zone 2 and 3 meet, was recognized and it was evaluated if the trim was done in the correct zones of the claw, with special emphasis on whether they trimmed behind the heel fulcrum on the stabilizer claw. Trimming behind the heel fulcrum on the stabilizer claw was accepted if done in an attempt to remove damaged horn. The authors examined if the trim left the heel height equal and perpendicular to the pastern (Fig. 2 - blue lines). This was done on non weight-bearing claws, supporting the claws at the coronary band with one hand to make the dorsal claw wall level between the medial and lateral claw on each leg, while examining if the heel height was equal between the lateral and medial claw, on a line perpendicular to the pastern. This was done as described by Toussaint Raven (1985). After the claw trimmer finished the trim we evaluated the balance of the sole surface controlling if the 4 points made by the pressure ridge and the heels constitute a plane sole perpendicular to the pastern (Fig. 2 - red $\times$). Lastly, the axial wall was examined as it should be perpendicular to the walking surface while bearing weight (Fig. 2 - purple lines).

Figure 2: *Claw trimmed with the WLAM. Validation criteria: Balance (red), heel fulcrum (green), heel height (blue), break over point (yellow), axial wall (purple). Edited private photo*

This yielded dichotomous results based on whether each of five parameters was trimmed in accordance with WLAM (see appendix B for data collection chart).

Prevalence of discrepancies were calculated on leg level for each parameter and as an overall percent discrepancy of the total amount of inaccuracies divided by the total amount of possible inaccuracies across all parameters. Shapiro-Wilk test (Shapiro and Wilk, 1965) was used to check if data was normally distributed. A Wilcoxon Rank Sum Test (Wilcoxon, 1945) was performed to assess if there were significant differences between the number of discrepancies from the left to the right leg. To calculate if there was a difference in the percent discrepancy between the trimmers, a pairwise Wilcoxon Rank Sum Test was performed with Bonferroni p-value correction.

2.3 Claw trimming procedure and effect on CHDL

The differences in technique and the final results between the 6 claw trimmers was evaluated quantitatively by the authors but also through qualitative questioning and descriptions by the trimmers. The 6 chosen claw trimmers were all originally trained in older trimming techniques, mainly the DAM, and had all participated in re-training with the WLAM in the autumn of 2018 when the method was introduced to the Danish claw trimmer curriculum. Each of the six claw trimmers were asked to deliver herd ID on all farms in which they had been trimming and making claw health records since the 1st of October 2016.

- Claw trimmer A delivered 20 herds
- Claw trimmer B delivered 20 herds
- Claw trimmer C delivered 24 herds
- Claw trimmer D delivered 12 herds
- Claw trimmer E delivered 11 herds
- Claw trimmer F delivered 4 herds

Inclusion criteria for herds

- Having used one of the 6 chosen trimmers for at least 4 years.
- Having the claw trimmer use the claw health recordings for at least 4 years.
- Having no major changes in the housing, flooring, and bedding along with no changes in milking systems and frequency.

Of all 91 herds we were able to get in contact with 78 herd owners who were all positive about participating in the project. All 78 herds were contacted by telephone and asked about changes in housing, flooring and bedding and changes in their milking systems during the study period. Since different environments impacts the prevalence of lameness (Cook et al., 2016) herds were required to have no changes in the housing and milking of the animals. 13 herds were excluded based on changes on the herd within the study period and the remaining herds were assumed to have only changed the trimming method within the study period. Included herds (n = 65) received at least 1 email with a data extraction permit and instructions in returning it. These extraction permits were needed to access the claw health recordings in the Danish Dairy Management System. 71% (46/65) of herd owners sent back the extraction permit and from these we choose the 6 biggest herds fulfilling the criteria from claw trimmer A-E, and the only 3 herds fulfilling the inclusion criteria from trimmer F. 1 herd from trimmer B and E was removed as the extracted data was lacking claw health recordings for longer periods. This is thought to be caused by the trimmer not making recordings on every visit rather than errors in the data logging or extraction process. After this selection, a systematic review of the included herds was performed to determine the trimming strategy (frequency and the number of cows trimmed at each visit) for each herd and 2 herds with major changes were found. 1 herd from trimmer B and 1 herd from trimmer F had trimmed all cows every 4 months during the DAM period but during the WLAM the frequency increased to every month while the number of cows per visit decreased. This result in 29 herds in total with a mean herd size of 194 cows in milking (mean herd size range per trimmer: 150-264 cows) which is fairly close to the Danish mean of 225 cows per herd in 2021[7]. The breeds consisted of Danish Holstein (24 herds, 83%), Danish Jersey (3 herds, 10%), Crossbreeds (1 herd, 3%), and Danish Red Dairy (1 herd, 3%), resulting in a fair representation of the general Danish dairy herds as approximately 65% is Danish Holstein, 12% is Danish Jersey, 6% is Danish Red Dairy, and the remaining 17% is crossbreeds and minor breeds. 1 (3%) of the herds was driven organic, somewhat corresponding with the Danish mean of 10% organic herds[7]. The study period was determined to be 2 years with each of the trimming methods. The first course in WLAM in Denmark was held in October 2018 with a follow-up in march 2019 meaning full compliance to WLAM should occur after march 2019 with a transition period of 3 months which was excluded making the study period as follows: The DAM period stretches from 1/10-2016 to 1/10-2018, while the WLAM period stretches from 1/5-2019 to 1/5-2021.

[7] See: https://www.seges.dk/da-dk/fagomraader/kvaeg/tal-og-fakta-om-kvaegproduktion/maelkeproduktion (Accessed on 17/12-2021)

Data handling and statistical method

Extracted data from the Danish Dairy Management System consisted of all claw health recordings on cows trimmed in the study period and if a cow at any time within the study period was claw trimmed, all previous recordings on the same cow was included in the extracted data together with the following information:

- Herd ID
- Trimmer ID
- Cow ID
- Trimming date
- Parity
- Calving date
- Race
- Date of birth
- Lesion and claw trimming recordings on cow level

The extracted data consisted of 323,208 entries. Some unwanted herds, not included by the study criteria were incidentally included in the data set. Initial tidying removed unwanted herds, herds with different trimming intervals between the two periods, and faulty recordings lacking one or more information which leaves 280,831 entries. Recordings made outside of the study period was removed, leaving 165,521 entries. Trimming dates with less than 20 cows were excluded as these recordings most probably originate from emergency visits with focus on salvage trimming more than routine trimming. As such trimming dates with more than 20 cows are assumed to be routine trimmings, representative of the distribution of claw lesions in the herds and this leaves 163,409 entries. Recordings of skin-related lesions and duplicates along with recordings performed on heifers were removed from the data set leaving only CHDL's (SH, SU, DS, WLF, and WLA) on lactating and dry cows. This leaves 104,541 entries of which 56,984 are claw trimming recordings and 47,557 are CHDL recordings. Of the 56,984 claw trimming recordings 48% (27,440/56,984) are DAM trimmings and 52% (29,544/56,984) are WLAM trimmings. The recordings are from claw trimmings performed on 13,500 different cows during the study period. For further calculations cows calving for the first time within each of the study periods was isolated in a separate data set. This leaves 35,487 entries, where 21,161 was claw trimming recordings and 14,326 was CHDL recordings. Of the claw trimmings, 42% (8,843/21,161) were DAM and 58% (12,318/21,161) were WLAM.

Considering each cow was trimmed several times in each study period, the recordings are not independent, since it is fair to assume a lesion can persist between two trimmings. The transition period between the two study periods, reduces the risk of a lesion persisting from the DAM period through the transition period to the WLAM period. This was done in an attempt to reduce the effect of dependency.

A generalized linear mixed effect model was used with the prevalence of the given lesion as the outcome variable and method as explaining variable together with the herd as a random effect. The model was run containing all trimmers, and afterward, a leave-one-out cross-validation was performed to further elaborate the results on the effect contributed by each trimmer. The model was repeated on the data set only containing cows calving for the first time within each period to investigate the effect of being trimmed with only one method, and to account for the non-independence between the study periods.

The prevalence (p) in the herd (i) trimmed with the method (j) is given by:

$$logit(p_{ij}) = \beta_0 + \beta_1 method_{ij} + u_i$$

$$u \approx N(0, \sigma_u^2)$$

Where β_1 is the coefficient for the method (WLAM) and u_i is a random normally distributed effect from the herd. The coefficient and its 95% confidence intervals (CI) were used to calculate the odds ratio (OR) and the corresponding 95% CI. Leave-one-out cross-validation was performed, as the model were repeated leaving out one claw trimmer each time.

OR's of lesion development when exposed to trimming with WLAM compared to DAM was calculated. OR can be interpreted as: OR=1 exposure do not affect the odds of the outcome. OR>1 exposure is associated with higher odds for the outcome. OR<1 exposure is associated with lower odds of outcome. Thus if a trimmer is removed in the cross-validation and the OR decrease compared to the model analyzing all trimmers, the removed trimmer has a higher OR than the rest combined, and therefore less odds reducing effect of the WLAM.

3 Results

3.1 Validation of recordings

The agreement between the authors and the claw trimmers recordings of claw lesions are presented in Table 2, showing κ and percent agreement.

The highest level of agreement was found with trimmer C and E for WLA ($\kappa = 1.00$) showing perfect agreement and the second highest was found with trimmer E for SU ($\kappa = 0.79$) showing substantial agreement. SH for trimmer A ($\kappa = 0.64$), SU and WLA for trimmer D ($\kappa = 0.62, \kappa = 0.65$), and DS for trimmer E ($\kappa = 0.63$) all showed substantial agreement as well (Table 2).
Based on the κ values, SH for trimmer A, D, and F shows acceptable agreement along with SU for trimmer A, C, D, and E. Trimmer C, D, and E all have an acceptable agreement for WLA, but only trimmer F had acceptable agreement for WLF and trimmer E for DS. When considering the mean κ acceptable agreement for SH, SU, and WLA recordings was found. Trimmer B and D exhibits negative κ values for WLF and DS respectively. This occurs when observers exhibit agreement at less than random intervals suggesting disagreement between the two (Table 2).

When looking at the percent agreement we see different results as all CHDL's show substantial or almost perfect agreement except for WLF showing moderate agreement for all trimmers. When accepting 61% agreement as the lowest acceptable agreement we find SH, SU, WLA, and DS to have acceptable mean percent agreement.

3.2 Validation of trimming technique

Validation of trimming technique was done on 30 to 37 cows per claw trimmer. For each hind leg the trimming output was evaluated on 5 parameters regarding the trimmers discrepancy towards the principles of WLAM.

Table 2: Number of lesions found by authors (no), κ, and %-agreement (%) on cow level

	SH			SU			WLF			WLA			DS		
	no	κ	%	no	κ	%	no	κ	%	no	κ	%	no	κ	%
A (n=37)	33	0.64	94.6	5	0.44	89.2	28	0.02	43.2	0	NA	NA	9	0.18	67.6
B (n=34)	27	0.21	82.4	0	NA	NA	22	-0.03	35.2	1	0.00	97.1	1	0.00	97.1
C (n=25)	18	0.40	76.0	3	0.47	92.0	13	0.21	60.0	1	1.00	100.0	3	-0.06	84.0
D (n=36)	19	0.46	72.2	8	0.62	86.1	25	0.13	47.2	1	0.65	97.2	2	0.00	94.4
E (n=28)	21	0.30	71.1	6	0.79	92.9	23	0.16	46.4	1	1.00	100.0	16	0.63	82.1
F (n=38)	32	0.44	78.9	0	NA	NA	30	0.42	71.1	0	NA	NA	4	0.37	92.1
Mean		0.41	79.2		0.58	90.6		0.15	50.5		0.66	98.5		0.19	86.2

n: number of cows validated.
NA: Lesion was not represented during validation.
SH: Sole hemorrhage, SU: Sole ulcer, WLF: White line fissure, WLA: White line abscess, DS: Double sole

The percent discrepancy on leg level ranges from 0% to 94%, with 0% indicating full compliance to WLAM are obtained on every leg (Table 3). The lowest percent discrepancy is on the axial wall, with a range from 0% to 6%, while the highest rate is on heel fulcrum, ranging from 0% to 94%. For trimmer B, D, and F we find a significant difference (*p<0.05*) in their discrepancy between left and right leg regarding heel fulcrum (B, F) and BOP (D).

A Shapiro-Wilk test showed that the number of discrepancies per cow was not normally distributed (*p<0.05*).

Table 3: Percent discrepancy for each parameter on leg level

	Break Over Point		Heel height		Balance		Heel fulcrum		Axial wall	
Trimmer	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
A (n=36)	6%	3%	3%	14%	11%	14%	86%	94%	0%	0%
B (n=34)	9%	24%	21%	6%	12%	26%	*15%	*41%	0%	6%
C (n=30)	17%	20%	3%	7%	20%	13%	20%	23%	0%	3%
D (n=37)	*11%	*0%	16%	5%	19%	5%	0%	3%	3%	3%
E (n=29)	0%	3%	7%	0%	0%	7%	10%	7%	0%	0%
F (n=32)	9%	16%	*3%	*19%	16%	6%	*16%	*47%	0%	0%

n: Number of validated cows per trimmer.
*: Significant (p<0.05) difference between left and right leg.

The overall percent discrepancy and the percent for left and right leg was calculated for each trimmer (Table 4) showing that trimmer B, D, and F still had significantly more discrepancies (*p<0.05*) on either the right or left leg. The range of discrepancy, per cow, for each trimmer varies from 3.4% to 23.1% with trimmer A having the most discrepancies and trimmer E having the least discrepancies (Table 4). There are five groups of trimmers according to a pairwise Wilcoxon Rank Sum Test, which can be ranged from least to most compliant. If groups share a Greek letter, they are not significantly different (*p<0.05*).

Group α contains trimmer E with the highest level of compliance to the WLAM, group $\alpha\beta\gamma$ contains trimmer D, group $\beta\gamma\delta$ contains trimmer C and F, group $\gamma\delta\epsilon$ contains trimmer B and group ϵ contains trimmer A with the lowest level of compliance to the WLAM (Table 4).

Table 4: Percent discrepancy for each trimmer on cow level

Trimmer	Percent discrepancy	%-discrepancy left	%-discrepancy right
A	$^{\epsilon}$23.1%	10.6%	12.5%
B	$^{\gamma\delta\epsilon}$15.9%	*5.6%	*10.3%
C	$^{\beta\gamma\delta}$12.7%	6.0%	6.7%
D	$^{\alpha\beta\gamma}$6.5%	*4.9%	*1.6%
E	$^{\alpha}$3.4%	1.7%	1.7%
F	$^{\beta\gamma\delta}$13.1%	*4.4%	*8.7%

*: Significant ($p<0.05$) difference between left and right leg.
$\alpha\beta\gamma\delta\epsilon$: No significant ($p>0.05$) difference between trimmers

Detailed descriptions of the trimming techniques in the order used by each claw trimmer, the main points from our interview and validation, and how often the trimmer cut too deep, resulting in a healthy claw bleeding is presented here:

Claw trimmer A

- Used a team of 3 trimmers
- Two helpers trimming the front legs and the main trimmer working on the hind legs.
- The order of the trim is: Left hind and right hind by the main trimmer. In the meantime, the helpers trimmed the front legs
- Trims zone 1, 2, 3, and 4 on the stress claw with an angle grinder
- Trims zone 1, 2, 3, and 4 on the stabilizer claw with an angle grinder. The trimmer explains that trimming in zone 3 and 4 on the stabilizer claw are mainly done to visualize the horn quality
- Modelling of the sole done with an angle grinder
- Trims toe length if needed
- Curative trimming and treatments if needed

According to claw trimmer A the important output of the trim is a good balance and weight distribution, while moving more weight from the heel to the toe. Claw trimmer A further described a bigger need for trimming the heel now compared to the DAM period. Claw trimmer A cut too deep in the toe 1 time during the validation. According to our validation trimmer A's least compliant parameter was trimming the stabilizer claw behind the heel fulcrum on $86-94\%$ of the legs. It can be noted that trimmer A routinely trimmed zone 4 on the stabilizer claw. The overall percent discrepancy groups trimmer A as the least compliant with WLAM, in group ϵ.

Claw trimmer B

- Used only 1 trimmer
- The order of the trim is: Left front, right hind, left hind, right front
- Before entering the chute the dorsal interdigital cleft is quickly assessed for the presence of interdigital hyperplasia
- Modelling of the sole with an angle grinder
- Trims zone 1, 2, and 3 on the stress claw until level with the stabilizer claw
- Trims zone 1 and 2 on the stabilizer claw
- Trims toe length, always
- Trims axial wall
- Claw is left to hang loose and visual control of the balance with corrective trimming if needed
- Cleans interdigital cleft with a hoof knife to look for lesions
- Curative trimming and treatments if needed

According to claw trimmer B, the important output of the trim is a plane sole and an even heel height. Claw trimmer B explains that trimming the toe length has always been practiced but when using the WLAM the stabilizer claw is trimmed less than with the DAM. Claw trimmer B cut too deep in the toe 3 times during the validation and the toe length was trimmed on every claw. According to our validation trimmer B's least compliant parameter was trimming the stabilizer claw behind the heel fulcrum on $15-41\%$ of the legs. The overall percent discrepancy groups trimmer B as the second least compliant with WLAM, in group $\gamma\delta\epsilon$.

Claw trimmer C

- Used a team of 2 trimmers, each working exclusively on one side of the chute

- The order of the trim is: Left hind and right front simultaneously then right hind and left front
- All 4 feet were cleaned using running water
- Modelling of the sole with an angle grinder
- Trims zone 1, 2, and 3 on the stress claw until level with the stabilizer claw
- Trims zone 1 and 2 on the stabilizer claw
- Trims toe length if needed
- Claw is left to hang loose and visual control of the balance with corrective trimming if needed
- Curative trimming and treatments if needed

According to claw trimmer C the important output is weight distribution and sole thickness. Claw trimmer C cut too deep in the toe 1 time during the validation. According to our validation trimmer C's least compliant parameter was trimming the stabilizer claw behind the heel fulcrum on $20-23\%$ of the legs. The overall percent discrepancy groups trimmer C together with F as the third least compliant with WLAM, in group $\beta\gamma\delta$.

Claw trimmer D

- Used only 1 trimmer
- The order of the trim is: Left front, left hind, right hind, and right front
- Looks at claws and estimates cow weight before it enters the chute
- Modelling of the sole with an angle grinder
- Trims zone 1, 2, and 3 on the stress claw until level with the stabilizer claw
- Trims the stabilizer claw in zone 1 and 2
- Trims toe length if needed
- Trims axial wall, if a wide white line is present
- Claw is left to hang loose and visual control of the balance with corrective trimming if needed
- Trimming of the pressure ridge, where zone 7 meets zone 2, is often performed
- Curative trimming and treatments if needed

According to claw trimmer D the important output is a plane sole surface. Claw trimmer D also hypothesized that the WLAM increased the risk of toe necrosis and hypothesized that herds with more frequent visits had reduced prevalence of claw deformities. Claw trimmer D cut too deep in the toe 1 time. According to our validation trimmer D's least compliant parameter was obtaining balance of the sole with discrepancies on $5-19\%$ of the legs. The overall percent discrepancy groups trimmer D as the second most compliant with WLAM, in group $\alpha\beta\gamma$.

Claw trimmer E

- Used 2 trimmers, each working exclusively on one side of the chute
- The order of the trim is: left and right front simultaneously then left and right hind
- All 4 claws are cleaned using compressed air and the dorsal claw wall is cleaned with a hoof knife
- Cleans skin lesions with a mild soap solution followed by compressed air
- Trims zone 1, 2, and 3 on the stress claw until level with the stabilizer claw
- Trims zone 1 and 2 on the stabilizer claw
- Evaluates sole thickness, intermittently using hoof testers
- Trims toe length if needed
- Modelling of the sole with a hoof knife
- Evaluates balance and heel height while claw is aligned by hand, with corrective trimming if needed
- Curative trimming and treatments if needed

According to claw trimmer E the important output is a plane sole with a good balance and weight distribution together with good contact between the floor and pressure ridge. Claw trimmer E also emphasize the importance of being able to recognize the correct placement of the heel fulcrum when using the WLAM. The helper asked the main trimmer when in doubt on trimming and recording decisions. According to our validation trimmer E's least compliant parameter was trimming the stabilizer claw behind the heel fulcrum on $7-10\%$ of the legs. The overall percent discrepancy groups trimmer E as the most compliant with WLAM, in group ϵ.

Claw trimmer F

- Used 2 trimmers per chute, one trimming the front legs and the other trimming the hind legs, alternating between the trimmers

- The order of the trim is: right front and hind simultaneously followed by left front and hind
- Trims the stress claw in zone 1, 2 and 3
- Trims the stabilizer claw in zone 1 and 2
- Trims toe length using a modified rim cut, leaving the tip of the toe rounded
- Modelling of the sole with an angle grinder
- Lets claw hang to evaluate balance and trim axial wall overgrowth
- Evaluates sole thickness by applying pressure to sole with the protective screen on the angle grinder
- Cleans interdigital cleft on hind legs with water to look for lesions
- Preventive digital dermatitis treatment applied topically in the interdigital cleft on hind legs of all cows
- Curative trimming and treatments if needed

According to claw trimmer F the important output of the trim is leaving substantial heel height and a good balance between lateral and medial claw. Trimmer F asserts not to remember the principles of the WLAM and still trims the same way as before the WLAM, with the only exception being the trimming of the toe length which was avoided before the introduction of WLAM as it was prohibited during the DAM period. Trimmer F hypothesized a risk of claw wall fractures if a thin and elongated claw wall at the toe is not managed, leading to toe necrosis. According to our validation trimmer F's least compliant parameter was trimming the stabilizer claw behind the heel fulcrum on $15-41\%$ of the legs. The overall percent discrepancy groups trimmer F as the third least compliant with WLAM, together with trimmer C in group $\beta\gamma\delta$.

3.3 Comparison of DAM and WLAM based on CHDL prevalence

Using a generalized linear mixed effect model, we analyze the change in prevalence of a given lesion between the two methods, with the herd as a random effect (see appendix C for R output). OR's were calculated from the coefficients and leave-one-out cross-validation were performed, and the results are presented in Table 5.

The overall OR for all trimmers vary between the lesions from OR = 0.59 for WLF to OR = 1.34 for DS. 4 lesions (SH, SU, WLF, and WLA) show OR's and CI's below 1 indicating that trimming with WLAM is associated with reduced odds of getting these CHDL's compared to trimming with DAM (Table 5). The leave-one-out cross-validation mainly yielded results with CI's below 1, except for SH when removing trimmer D and SU when removing trimmer E. On the contrary the WLAM is associated with reduced odds of DS when removing trimmer A. The large variance, from OR = 0.31 for SH when removing trimmer A to OR = 1.45 for SH when removing trimmer D, suggests an interaction between trimmer and method (Table 5).

Table 5: Odds ratios with 95% CI [$_{2.5\%}50\%_{97.5\%}$] for the five claw horn disruption lesions for all trimmers

	SH	SU	WLF	WLA	DS
All	$_{0.68}0.74_{0.80}$	$_{0.62}0.72_{0.83}$	$_{0.53}0.59_{0.65}$	$_{0.51}0.63_{0.77}$	$_{1.17}1.34_{1.54}$
A	$_{0.28}0.31_{0.34}$	$_{0.45}0.53_{0.62}$	$_{0.45}0.50_{0.56}$	$_{0.45}0.57_{0.71}$	$_{0.56}0.67_{0.79}$
B	$_{0.68}0.74_{0.81}$	$_{0.63}0.73_{0.85}$	$_{0.54}0.60_{0.66}$	$_{0.51}0.62_{0.76}$	$_{1.17}1.34_{1.54}$
C	$_{0.71}0.79_{0.87}$	$_{0.61}0.71_{0.83}$	$_{0.57}0.64_{0.72}$	$_{0.51}0.65_{0.81}$	$_{1.33}1.54_{1.77}$
D	$_{1.32}1.45_{1.59}$	$_{0.67}0.79_{0.94}$	$_{0.49}0.56_{0.63}$	$_{0.56}0.72_{0.93}$	$_{1.31}1.52_{1.76}$
E	$_{0.75}0.82_{0.90}$	$_{0.71}0.84_{1.01}$	$_{0.63}0.71_{0.80}$	$_{0.50}0.62_{0.77}$	$_{1.52}1.79_{2.11}$
F	$_{0.64}0.69_{0.76}$	$_{0.64}0.75_{0.88}$	$_{0.50}0.56_{0.63}$	$_{0.51}0.63_{0.78}$	$_{1.20}1.37_{1.58}$

SH: Sole hemorrhage, SU: Sole ulcer, WLF: White line fissure, WLA: White line abscess, DS: Double sole.
All: All trimmers included in the data set
A-F: The trimmer left out in the cross-validation

The cross-validation reveals a difference between the individual trimmers effect of the method as the OR's varies significantly for SH, SU, and DS with minor variation within WLF and WLA (Table 5). To quantify this difference trimmers are ranked within each lesion based on the resulting OR when the trimmer is removed. The lowest OR of the cross-validation within each lesion, marks the trimmer with the least effect in reducing the odds of the specific lesion and the highest OR marks the trimmer with the most effect. This gives a rank with 6 levels of effect within each of the 5 lesions. Based on the mean rank each trimmer is given an order (I to VI) corresponding to their effect of the WLAM (Table 6). This order places trimmer A as the trimmer with the least overall odds reducing effect of the WLAM and trimmer E as the one with the most overall odds reducing effect.

Table 7 shows the OR's between the DAM and the WLAM period when only including recordings on cows that calved the first time within each period. Here it can be seen that only for SH, WLF, and WLA, the WLAM is associated with reduced odds, while it has an odds increasing effect on DS. No significant association of the WLAM can be seen on the prevalence of SU. Secondly, it can be noted that the 95%

Table 6: Ranking of trimmers based on odds ratio from cross-validation (Table 5)

Trimmer	SH	SU	WLF	WLA	DS	Mean rank	Order
A	1[0.31]	1[0.53]	1[0.50]	1[0.57]	1[0.67]	1	VI
B	3[0.74]	3[0.73]	4[0.60]	3[0.32]	2[1.34]	3	V
C	4[0.79]	2[0.71]	5[0.64]	5[0.65]	5[1.54]	4.2	III
D	6[1.45]	5[0.79]	2[0.56]	6[0.72]	4[1.52]	4.6	II
E	5[0.82]	6[0.84]	6[0.71]	2[0.62]	6[1.79]	5	I
F	2[0.69]	4[0.75]	3[0.56]	4[0.63]	3[1.37]	3.2	IV

SH: Sole hemorrhage, SU: Sole ulcer, WLF: White line fissure, WLA: White line abscess, DS: Double sole.
Order: I to VI with I having the highest average effect of WLAM and VI the lowest.

CI has widened across all lesions.

Table 7: Odds ratio with 95% CI [$_{2.5\%}50\%_{97.5\%}$] for the five claw horn disruption lesions across all trimmers, but only for cows calving for the first time within each period

	SH	SU	WLF	WLA	DS
Odds ratio	$_{0.64}0.73_{0.83}$	$_{0.63}0.87_{1.2}$	$_{0.42}0.52_{0.63}$	$_{0.30}0.48_{0.79}$	$_{1.42}1.85_{2.43}$

SH: Sole hemorrhage, SU: Sole ulcer, WLF: White line fissure, WLA: White line abscess, DS: Double sole.

4 Discussion

4.1 Validation of recordings

The difference in agreement between the κ values and the percent agreement in this study seems large (Table 2). The advantage of κ over percent agreement lies in its ability to consider the possibility of raters guessing on their recordings, which is possible, but thought to be a rare occurrence among experienced claw trimmers. The difference found in this study between the κ value and percent agreement is thought to partly arise from a very low prevalence of WLA and DS during validation, which means the recognition of these few incidents has a large influence on the κ values where the percent agreement places more equal value in recognizing if the lesion is not present (Table 2). On the other hand, very high κ values are obtained when low prevalence lesions are recorded correctly. An example of this can be seen for WLA when comparing trimmer B and C, as percent agreement is only 2.9% lower while κ values are 100% lower for trimmer B. When looking at lesions with a higher prevalence (SH, SU, WLF) we find a bigger correspondence between κ values and percent agreement (Table 2). These differences make the comparison of κ and percent agreement challenging.

Different studies have previously investigated the agreement of Danish claw trimmers claw health recordings with an independent observer (Capion et al., 2008, Kviesgaard, 2013, Skovsgaard, 2018) and they find trimmers to be accurate in recognizing lesions under test conditions but find lesser agreement with the observers under practical conditions. Capion et al. (2008) generally finds higher agreement (SH: $\overline{\kappa} = 0.81$, white line lesion, similar to WLF+WLA: $\overline{\kappa} = 0.59$) compared to this study, while Kviesgaard, (2013) (SH: $\overline{\kappa} = 0.26$, SU: $\overline{\kappa} = 0.57$, DS: $\overline{\kappa} = 0.37$) finds a lower agreement compared to this study (Table 2). Skovsgaard, (2018) calculated percent agreement (SH mild/severe: $41\%/82\%$, SU mild/severe: $98\%/99\%$, WLF: 68%, WLA: 99%, DS: 97%), which is difficult to translate to κ values as explained earlier, but comparing with the percent agreement found in this study there seems to be equal levels of agreement. Hence 3 different studies repeated within 13 years comes to the same conclusion: Trimmers perform well under test condition, but practical recording seems to depend on trimmers opinion and experiences. The repeated lack of agreement found in these studies, rises concern that trimmers are taught well, but fail to apply this knowledge in their practical recordings. On the other hand, the similarity between the agreements in the 3 previous studies and the present study, raises the confidence in the continuity of the recording practice through the DAM and WLAM periods.

Earlier comparisons of educated and non-educated claw trimmers indicate little to no difference between the recordings made by the two groups suggesting some regularity across trimmers. This may be due to the educated trimmers hiring and training the uneducated, or perhaps a lack of extra expertise among the educated group (Skovsgaard, 2018). When considering the variation found in this study between only educated trimmers the latter proposal seems more convincing than the first. Holzhauer et al. (2006) found trimmers to agree more with other trimmers compared to a golden standard suggesting trimmers are able to find a common recording consensus after being trained together.

Even though the use of claw health recordings has been evaluated by other studies (Skovsgaard, 2018, Kviesgaard, 2013, Capion et al., 2008) the authors felt it necessary to validate the recordings of the specific trimmers chosen for this study. This was partially done to account for the different recording practices seen in the previous studies and partially to investigate the current recording practice of the chosen trimmers.

The authors spend approximately twice as much time compared to the trimmers to investigate the claw for lesions. This difference is thought to arise from the authors lack of routine, and as veterinary students we strive to have an eye for even the smallest details. Since most of the trimmers register fewer lesions compared to the authors, it is possible that even experienced trimmers can benefit from using more time to check for all types of lesions.

The agreement between the authors and trimmers varied greatly between trimmers and lesions with the largest intra-trimmer-variance being between DS ($\kappa = -0.06$) and WLA ($\kappa = 1.00$) for trimmer C. Only trimmer B did not achieve acceptable agreement, based on κ values, for any lesion. This variance is thought to arise from trimmer B's recording practice of the frequent occurring lesions, where very minute or almost non existing lesions were recorded.

It is difficult to determine the reason for the incongruities between trimmers and the authors because, besides the obvious pitfalls of not recognizing mild lesions, there seems to be a degree of selection among the trimmers regarding which lesions are important to record. This might arise from confirmation bias when trimmers only remember the theories supporting their view on claw trimming and recordings while discarding the contrary recommendations. Confirmation bias arises when people are biased towards confirming their existing beliefs. This might lead trimmers to underestimate the impact of some lesions while their opinions become more and more deviating as they feel confirmed in their different beliefs and reject the contrary knowledge. This will in most cases lead recordings to become less reliable. At the same time there is a risk of experiencing the Dunning-Kruger effect (Kruger and Dunning, 1999) when trimmers, because of their immense practical experience, feel over-confident in their knowledge about claw trimming, anatomy, and physiology. As a result, they deliberately make rules and exceptions for when and which recordings are important or redundant. These assumptions from claw trimmers may hinder their development towards more evidence based techniques. When validating the work of others it is important to consider the risk of observer bias where the observers might be prejudiced by their inherent cognition or the observed part might change behavior because of the presence of the observer. In the same way, trimmers may make an extra effort because of a renewed interest in their field. Especially when interviewing trimmers about their view on the WLAM and trimming in general there is a risk of the trimmers becoming more aware of their technique or the principles of the WLAM. This risk could be avoided by doing a blinded experiment, but when validating the claw trimmers it was not possible since the trimmers would always know that the authors were present. The trimmers were informed before the beginning of the validation that their technique and recordings were examined, but not on which parameters. This was done to minimize the risk of observer bias, and when the authors communicated it was done either with codes or by whispering as to not influence the claw trimmers decisions and recordings.

Despite these efforts, the extra time spent by the authors was often used by the trimmers as well which makes it possible that trimmers benefited from this prolonged time for evaluation of lesions during this validation compared to their normal routine.

Most of the trimmers explain they do not recognize the importance of registering mild SH, WLF, and DS. This results in a high level of disagreement in these lesions, as seen in Table 2. When the authors pointed at mild lesions and asked the trimmers, they were all able to both see and name the lesion correctly, just as found by previous studies (Kviesgaard, 2013, Skovsgaard, 2018). The trimmers told the authors that the recording of mild lesions would be too time-consuming and would make all cows seem sick or that mild lesions in their opinion were unavoidable, had no impact on health or production, or simply was present on all cows. This recording practice underlines the importance of communication and collaboration of farmers, claw trimmers and veterinarians, to facilitate improvements on claw health management. Trustworthy recordings are imperative for an enlightened and useful debate on the subject.

Inconsistent recordings reduce the credibility of claw health recordings in dairy databases, exemplified by very low κ values for WLF in Table 2. This means the low OR for WLF in Table 5 should be interpreted with caution. The authors are confident in the trimmers intra-observer agreement as they claim to record consistently through the study period and thus the reduced OR, found by the statistical model seems trustworthy, but it remains unclear exactly how severe the lesion needs to be, to be recorded as WLF.

The fear of making all cows seem sick was a concern for all the trimmers, as all interviewed claw trimmers had experiences with veterinarians misinterpreting their claw health recordings. Trimmers explained that some veterinarians perceived the large difference in claw health recordings between herds as an expression of the true prevalence in the herd. They had inadvertently compared this with a herd where claw health recordings were done less intense or perhaps not at all. This interpretation lead veterinarians to the conclusion that the herd with many recordings had more claw lesions even though the difference was not in the true prevalence but in the recordings made by the trimmer. Some of the trimmers explained that this type of miscommunication between claw trimmer, farmer, and veterinarian has led to farmers asking the trimmer to cease recording of claw health. Claw trimmer B expressed that they would not record fewer lesions to make the cows seem healthier, instead they insisted on recording even the smallest lesions to avoid bias in the data collection. This might have some positive effect in achieving a true prevalence, but there seems to be a risk of overreporting as trimmer B showed the lowest κ agreement of all trimmers on most lesions.

Even though trimmers advocate more precise and useful recordings, the interviews exemplify how they are often caught in a crossfire between farmers, researchers, and veterinarians having different expectations and assumptions about claw health recordings, where the trimmer can only try to balance the interests of the different parties, often by developing their own rules.

A possible solution for trimmers is to conform to the same consensus of recordings across herds enabling a more trustworthy data set and thus providing a more useful product for their customers. Bringing more value to the claw health recordings could help in preventing loss to subclinical disease when farmers have better tools for choosing and timing interventions. At the same time bringing more value to an existing expense of the farmer could be important in the compliance of the farmer to more thorough trimming methods with more time spent per cow.

Claw health recordings are not exclusively used in the individual herd management, but also in national breeding programs. This accentuates the importance of precise recordings. For the breeding programs to select for healthy claws; reliable recordings are needed, especially because the heritability of claw lesions was found to be low (Heringstad et al., 2018).

Though it is difficult establishing the reason for the incongruity it is safer to determine that these recordings should be used with caution as the true prevalence found on the day of validation vary from the prevalence of recordings in the Danish Dairy Management System.

The unstructured interview format used in the present study results in a more free and agile interview. It may result in answers difficult to compare between interviewees but the important issues to the individual claw trimmer can be discussed in greater detail compared to a structured interview. Even though the interview was primarily conducted after the validation, the risk of trimmers changing behavior or answers based on the questioning prevails. A questionnaire could be used to quantify the opinions and practices of the claw trimmers, but the liberty of the unstructured interview was preferred to account for the large differences in opinions.

The authors were surprised, that even among claw trimmers selected based on good recordings and with an interest in the evolution of claw health, we found a variation in the technique, recordings, and efficacy of the method. This causes concern, that this variation is even larger between the average claw trimmer, which can impede the generalizability of the present study.

4.2 Validation of trimming technique

Even though all 6 claw trimmers had participated in courses training them in the use of the WLAM, it quickly became evident that not all claw trimmers considered their trimming technique to conform with the WLAM, but more to be a combination of the WLAM and earlier practiced methods. New trimmers only trained in the WLAM, is expected to comply with the method to a higher degree, limiting the variation between trimmers.
The practice of shortening the toe length caused the trimmers many frustrations. The oldest trimmers explained how this practice was normal before the DAM, during which it became prohibited, while in the WLAM it is again common practice. These changes in recommendations over time seem to undermine the importance of the recommendations as trimmers lose faith in the scientific background. Claw trimming courses in Denmark primarily has a practical focused curriculum which might inadvertently widen the gap between the dynamic scientific world sought-after by most veterinarians and the more static aspect of practical trimming represented by most professional claw trimmers. All trimmers except for E explained how they trimmed the toe-length when trimming with the DAM even though this was not allowed. This exemplifies how the trimmer's decisions on how to interpret a method have a great impact on its use, and most likely also its effect. Because the DAM method was not validated in this study it is difficult to know exactly how well the different trimmers conformed with the DAM principles, but the confidence remains in the trimmer's ability to use the same methods consistently through the study periods.

The discrepancies with the principles of the WLAM were evaluated quantitatively by scoring the different choices of the trimmer as compliant or non-compliant with the WLAM. This shows a difference between the trimmers in their ability to trim according to the WLAM principles (Table 3). No trimmer obtained 0% percent discrepancy in their trimming technique (Table 4), which shows that even routine trimming, consist of compromises between what is optimal and what is possible. In the interviews with the trimmers, it appears this compromise was one of the biggest dilemmas of claw trimming because they were often not able to trim the claws without deviating from the method.

In the method used for validation of trimming it is difficult to consider the many compromises necessary when trimming under practical conditions. In an attempt to mitigate this challenge the validation was based on the final claw conformation rather than in which way the trimmers obtain this. An example is that 3 different uses of the angle grinder, when trimming toe length, was observed, but all were evaluated equally, as long as a correct BOP was established according to the method. Another difference in the validation of trimming technique is trimmer A choosing to trim behind the heel fulcrum on almost all claws. This yields a very high percent discrepancy compared to trimmer B, who trimmed the toe length on almost all cows with much lower percent discrepancies. This is caused by the fact that some cows need trimming of the toe length while almost no cows need trimming behind the heel fulcrum and it exemplifies how some parameters are more important but also more difficult to comply with. Only trimmer D mentioned the weight of the cow as a parameter to consider before trimming, suggesting that trimmer D performed a more thorough evaluation of the animal, compared to the other trimmers, but it remains unclear how this information was used to alter the trimming decisions. Claw trimmer B, C, and D all let the claw hang loose to perform visual control of the heel height and balance between the paired claws. This may increase the risk of not representing the claw correctly, since a claw fixated on the metatarsals with the claw hanging loose, has the ability to move back and forth, up and down while the paired claws of each limb may also change position in relation to each other. When the heel height and balance is evaluated on lifted claws it should be performed as described by Toussaint Raven (1985). The chutes have a hydraulic guard which can support the claws, but this rarely results in a level presentation of the paired claws on each leg. Evaluating the balance is particular import to the WLAM as White and Daniel (2017) describes how the WLAM seeks to adapt the equine term of balance where, under optimal conditions, the foot and leg should be evaluated both caudally and laterally, but this practice is hard to perform during practical claw trimming.

Even though claws with deformities were excluded, the variance of healthy cows makes the subject challenging to binary quantify. The validation used in the present study consisted of 5 dichotomous parameters which was assessed exclusively by the authors on the final claw conformation. This design do not allow the claw trimmer to explain why a discrepancy is made, even if it is done to make a better trim for the cow.

When regarding the percent discrepancies it becomes evident that trimmer B and F have more discrepancies on the right leg and trimmer D on the left leg for some of the parameters (Table 3), but also when calculating the overall discrepancies (Table 4). This surprises the authors as trimmers were expected to be able to trim the left and right leg with equal compliance to the principles of the chosen method. Since this does not seem to be the case the authors search for handedness in the setup of the trimmers. Examples of handedness are found for all trimmers as they are all right-handed and therefore use the angle grinder in a right-handed manner. Since this is equal for all trimmers, and because some trimmers are skewed to the right leg and some to the left leg, the right-handedness is not thought to be the reason. Other causes should be considered, but it is possible that some trimmers compensate better for this difference. All trimmers except for trimmer E use extra protective screens on the right side of their angle grinders, which may interfere when trimming one side compared to the other. The paired claws on each foot require individual trimming, therefore it may be more difficult to trim the stabilizer claw correctly when it is to the left of the stress claw or vice versa, especially as it is opposite on the front legs. Another example of handedness in the trimming is the order of the trim. Trimmer B, D, and F have more discrepancies on the hind leg, which is trimmed first and/or right after trimming a front leg. This suggests that trimming of the hind leg right after a front leg disturbs the trimming decisions appropriate to the hind leg, or the first leg on each cow serves as a calibration to the specific trimming needs of each cow. No single reason is found to the difference between right and left-sided discrepancies, but a combination of several, known and unknown, factors is thought to be the cause.

The trimmers have various views on which is the most important aspects of the trimming, but most agrees on a plane sole surface along with correct weight distribution between medial and lateral claws to be important aspects. This shows that the trimmers agree on the purpose of trimming in general, even though there is a noticeable difference in their compliance, arguments, and effect of their work.

4.3 Comparison of DAM and WLAM based on CHDL prevalence

The difference between the methods, found by the model, suggests reduced OR's for SH, SU, WLF, and WLA when using the WLAM. The findings of the present study are similar to the findings of Cannings (2021). A significant reduction in odds is found for all lesions except for DS, where a significant increase in odds is present. The leave-one-out cross-validation exhibits the interaction between trimmer and method, shown by the changes in OR's when removing individual trimmers from the method (Table 5). Thus the method has a different effect regarding which trimmer is using it. The difference between trimmers not only change the odds but, in some instances changes the association of the WLAM from reducing the odds to increasing the odds. During the leave-one-out cross-validation, a significant decrease in odds for WLF and WLA remains. But, for SH when trimmer D is removed from the model, a large increase in OR is found, associating the WLAM with larger odds for SH than the DAM. Similarly, when regarding SU and trimmer E is removed, the significant effect of the WLAM ceases. For DS the WLAM is associated with increased odds in the model. When cross-validation was performed, the same effect was present, except when removing trimmer A from the model (Table 5). The effect on DS could be caused by the reduced focus on trimming the whole sole surface with the WLAM, though other factors might influence the prevalence of DS. Randhawa et al. (2008) finds that biotin supplement in the feed eliminated the presence of DS and WLF in a group of 14 cows compared to a control group. These findings indicate that claw lesions may arise from the feeding of the animals as well as mechanical factors.

The risk factors of CHDL's is not fully understood as many factors seem to impact the claw health and presence of CHDL's. Griffiths et al. (2020) and Wilson et al. (2021) found thicker soft sole tissue and digital cushions in the lateral claws of the hind legs in cows with higher body condition scores. Newsome et al. (2017) find thinner sole soft tissue before the development of SU followed by an increase in thickness probably representing inflammation, but no direct correlation is found. Changes in sole soft tissue thickness after having one or more sole ulcers at the beginning of lactation, along with an increased risk of sole ulcers on cows with mastitis within the first 30 days of lactation are found by Griffiths et al. (2020). These findings indicate that both local and systemic factors can affect the development of CHDL's, besides the effect of trimming.

The digital cushions and formation of osteomas caudally on P3 has been found to have a relation to the amount of CHDL's (Newsome et al., 2016). Wilson et al. (2021) found the volume of the digital cushion of the lateral claws on the hind legs to be reduced by 1.0-0.2 mL per recorded CHDL during the lactating lifetime of the cows. It has proven difficult to establishing the role of the digital cushions regarding the development of CHDL's. They seem to be negatively correlated because smaller cushions are found on animals with more CHDL's (Wilson et al., 2021), but more knowledge is warranted. Newsome et al. (2016) found the presence of CHDL's increases the risk of exostosis formation caudally on P3. Again it is difficult to establish a causal relationship: If the CHDL's cause the exostoses or if the exostoses cause the CHDL's. More CHDL's are being found on cows with larger exostoses, which suggests a positive correlation between exostosis size and amount of CHDL's. This proposes that preventing the first CHDL is important compared to preventing subsequent lesions. The findings of Newsome et al.

(2016) is supported by Van Der Tol et al. (2004), who explains that pressure concentrated on the heel area might lead to damages in the functional structures of the heel as well as increased pressure on the flexor process of P3 on the corium, leading to SH and SU.

These relations between CHDL's and pathological changes in the caudal aspect of the claw suggest that benefits could be found in a trimming technique with emphasis on moving weight to the toe (Zone 1 and 2) rather than the heels (Zone 6) (Nuss et al., 2019). This coincides with trimmer A trimming behind the heel fulcrum on almost every leg (Table 3). It can be seen that when trimmer A is removed in the cross-validation, the OR of SH decreases significantly and a large, but non-significant, decrease in OR for SU is seen as well (Table 5). Thus trimmers A's use of the WLAM is associated with a lesser decrease in the odds, compared to the other trimmers. There is a risk of inaccurate recordings affecting this result, but considering the κ values and percent agreement seen in Table 2 the authors generally feel confident in recordings of SH and SU, and further because trimmer A shows acceptable agreements for SH and SU. Sole thickness and the heel height were mentioned by the trimmers as important output parameters and interestingly trimmer A felt it necessary to trim the heel height after having changed to the WLAM which might indicate that the WLAM is successful in moving force to- and mitigating wear in the toe generating a naturally thicker sole in the heel leading to an increase in heel height.

To minimize the differences of the study unit in the two study populations, the second data set was made, exclusively containing cows that had their first calf within each of the study periods. This was done in part to clarify the effect of being trimmed with only one method and to homogenize the study population within the two periods with regard to age and parity. This homogenization results in less representative populations since all older cows are removed, but it also reduces the noise created by older and perhaps chronically ill cows. It is noted, that the 95% CI of the OR's in Table 7 is wider than the OR's in Table 5, which is due to the much smaller sample size used for the calculations in Table 7. The thoroughness and the shared focus on weight distribution and sole thickness of the WLAM compared to the DAM, lead the authors to suspect a larger impact of the method on cows who had never been trimmed with another method. Considering Table 7 this is partly contradicted, as only SH, WLF, and WLA shows a reduction in the OR compared to the full model. For SU and DS, the OR's rose (Table 7) as an indication of increased odds during the WLAM period and for SU the effect is not significant while DS show a significant increase in odds from DAM to WLAM. When the model is used on the reduced population, the results exemplifies that the WLAM can still be associated with reduced odds of

SH, WLF, and WLA when it is the only trimming method used on the cows. This implies that the method not only is associated with reducing the prevalence, but it seems to be associated with preventing lesions when cows have never been exposed to the DAM. This result bears the risk of being heavily influenced by the treatment of heifers in the different herds, but since the selection of herds was based on having no changes in the stables, this effect is thought to be equal across the two periods.

Compared to Cannings (2021) who also finds an association of the WLAM with reduced odds of CHDL's, more trimmers and a lager sample size is used in this study. The larger study population gives a better representation of the average Danish dairy herd and thus transferability of the study is further strengthened. When including more herds the different effects of the herd management, feeding, and stable design may even out because all herds are slightly different and the more differences represented in the study group the more representative it becomes. To obtain as many herds as possible, thus enabling the authors to impose further selection criteria, we asked the 6 selected trimmers for herd ID from all herds in which they had been trimming and recording since the 1st of October 2016. This showed some difference between the trimmers, as the range of herds provided was from 4 to 24 herds. It is unclear if some trimmers only shared herd IDs where they felt an improvement of the claw health, which poses a risk of selection bias in the herd selection of this study. The differences in herds provided impaired the obtaining of the initial goal of 6 herds per trimmer. This, together with the differences in herd sizes, results in some trimmers representing more data entries than others and thus have a higher impact in our statistical model. This is sought to be accounted for by using the leave-one-out cross-validation.

4.4 General discussion

When the validation of trimming technique is compared to the OR's of the leave-one-out cross-validation, there seems to be a pattern connecting the trimmer's compliance with their OR's. The groupings of trimmers found in Table 4 correspond with the order of the trimmers found in Table 6 which is summarised in Table 8.

Table 8 shows that group α which has the highest level of compliance to the method also has the highest order (I), which means it has the largest association with reduced odds of CHDL's. Reversely group ϵ has the lowest level of compliance to the method and the lowest order (VI). This suggests a link between compliance to the WLAM and the extent to which the WLAM can be associated with reduced odds of

Table 8: Comparison of trimmer order and group from highest to lowest efficacy.

Order	Trimmer	Group
I	E	α
II	D	$\alpha\beta\gamma$
III	C	$\beta\gamma\delta$
IV	F	$\beta\gamma\delta$
V	B	$\gamma\delta\epsilon$
VI	A	ϵ

Order based on cross-validation OR's.
Group based on technique validation, groups sharing greek letters are not significantly different (p>0.05).

CHDL's.

The compliance among claw trimmers might vary, but a general goal of claw trimming is achieving balance between the paired claws and equal heel height. This was mentioned by most trimmers during the interviews, but the validation showed that all trimmers have discrepancies in these parameters even though they are seen as universally important across claw trimming methods. The increased focus on heel fulcrum and break-over-point in the WLAM is unique to this method. Therefore these parameters are expected to account for more of the association with reduced odds for CHDL's. This leads the authors to interpret a correct evaluation of heel fulcrum as a consequential parameter in gaining efficacy from the WLAM, but determining a correct BOP and trimming the toe length according to this is also important.

The sole thickness is also mentioned as an important factor by trimmer C. This parameter has been further investigated by Nuss and Paulus (2006) who finds that trimming of the stabilizer claw should be limited if the sole thickness of the stabilizer claw is to be the same as the stress claw. This is thought to be well implemented in the WLAM, as trimming of the stable claw is naturally limited by the heel fulcrum.

Other studies have performed controlled trial studies to illuminate the effect of different claw trimming methods (Ouweltjes et al., 2009, Gomez et al., 2013, Mahendran et al., 2017, Stoddard and Cramer, 2017). Some of these studies (Ouweltjes et al., 2009, Mahendran et al., 2017) do not find significant differences between the methods used. Retrospective observational studies enable easier access to much larger data sets, compared to controlled trials. The large data set makes it possible to discover smaller differences but has the disadvantage of not being able to determine causal relationships. The association of WLAM with reduced odds of CHDL's found by the present study, implies that the trimming method may have an effect on claw lesions. However, this effect may be too small to detect in controlled trials with moderately sized study populations.

Through a thorough selection of trimmers and herds the amount of noise created by changes in the herds or by the trimmers was sought to be reduced, but some factors were not possible to take into account. The teams of the different claw trimmers consisted in all instances of more than 1 person, the main trimmer with a different amount of helpers. Because of the study design, the main trimmer from each team persisted through the whole study period, but no records of the different helpers were available. This is thought to be most important for trimmer C and F because these trimmers had a separate chute with helpers trimming and recording on the same trimmer ID as the main trimmer, while the main trimmer exclusively worked on the main chute. During the validation, only the chute with the main trimmer was validated and when validating the trimming technique the main trimmer was preferred, when possible.

The authors find it appropriate to recommend some kind of cleaning of the claws to better visualize lesions hidden by manure. Trimmer A, B, C, and E all do some kind of cleaning: (A) trimming a thin layer on the whole sole surface (Zone 1-6), (B) scraping the interdigital cleft with a hoof knife, (C) running water, or (E) pressurized air and hoof knife to scrape dorsal claw wall. Even if it does not lead to more lesions detected, it gives the trimmer more time to evaluate the trimming decisions. Cleaning with the angle grinder as trimmer A did, is not recommendable, as it increases the risk of removing too much sole horn, especially in the heels (Zone 3, 4, and 6). Cleaning with the hoof knife in the interdigital cleft as trimmer B risks damaging the claw, surrounding structures, or interdigital hyperplasia if present. Furthermore it increases the risk of transferring infectious claw diseases, e.g. Digital dermatitis, between claws and cows (Yang et al., 2018, Gillespie et al., 2020). Only trimmer E makes sure that the dorsal claw wall was clean ensuring that the paired claws are level during the assessment. This seems to be an important starting point in the assessment of the trimming needs of the claw, since trimmer E obtains the lowest percent discrepancies in the balance parameter. There is to our knowledge no research on the effect of cleaning on trimming decisions and claw health in general.

Trimmer D hypothesized that the introduction of WLAM may lead to an increase in the prevalence of toe necrosis, because the evaluation of BOP and subsequent trimming of the toe length may lead trimmers to cut too deep, thus inducing toe necrosis. On the other hand, trimmer F hypothesized that toe necrosis would become less frequent with the WLAM because this method takes care of the elongated claw wall at the toe of the claw, minimizing the risk of claw horn fractures. Only trimmer E and F did not cut too deep in the toe during the validation, but it is difficult to determine the reason, the cause, the frequency, and the outcome of the error of cutting too deep. 2 of the trimmers included in this study showed different concerns regarding the prevalence of toe necrosis. Other miscellaneous actions was performed by the trimmers during the validation, eg. modified rim cut and routine trimming of axial and abaxial wall. These actions are not a specific part of the WLAM principles, but also not directly against the principles and it is unclear what effect they may cause.

Claw health is a multi-factorial problem, with a myriad of risk factors on both herd and cow level. Claw trimming strategy, herd size, hygiene routines, cubicle design, feeding, flooring, and bedding are all examples of herd level risk factors. Cow level risk factors can be: body condition, genetic predisposition, breed, season of calving, time of trimming, lactation stage and age (Capion et al., 2008). Thomsen et al. (2019) investigated the timing of claw trimming, finding claw trimming around dry off reduced the odds of developing sole ulcers in the following lactation, later he found that claw trimming within the last 4 weeks of gestation increased the odds of abortion (Thomsen et al., 2020). This displays timing as yet another important risk factor.

The WLAM is a relatively new method of claw trimming, and it is unknown how widely it is used. Because of the novelty of the method and paucity in the literature, some claw trimmers may be hesitant in adapting the method as they may feel more confident in the method they have been using for a long time. The elaborate and thorough steps, compared to more simple methods with less evaluation of the animal and fewer trimming decisions, may also intimidate trimmers.

Only 49% of Danish dairy herds asked trimmers to perform claw health recordings at claw trimming in 2020[2]. It is unclear why it is not more widely used and why the quality of the recordings varies between lesions and trimmers. This limits the usefulness of data in research and breeding management, but the most important use of the recordings should be in the individual herd in collaboration between the trimmer, farmer, and veterinarian. It is imperative that the veterinarian can provide relevant and evidence-based counseling on basis of a correct interpretation of precise claw health recordings. This requires that the farmer recognize an advantage in accepting the extra time necessary for the trimmer to perform precise recordings, and a veterinarian able to apply this knowledge in practical counseling. The increased time used per cow by the trimmer, results in an increased expense, which has to be covered by the improvement of claw health. Prolonged longevity of the cows may be sufficient to achieve an economic advantage of improved claw health, but an increased focus on the welfare and the sustainability aspect of fewer early culls might also be a good motivator. Rilanto et al. (2020) found the most prevalent reason stated by Estonian farmers for early culling was feet/claw disorders with 26.4%. When considering Leach et al. (2012) found that farmers on average took 65 more days to recognize lameness compared to an independent observer, it seems that better prevention and surveillance of claw lesions could reduce this loss. This is accentuated by Thomas et al. (2015) who is able to cure 69-85% of acutely lame cows, while only 15% of chronic cases was cured (Thomas et al., 2016).

5 Conclusion

This study consisted of three parts: Validation of claw health recording, validation of trimming technique, and a comparison of two claw trimming methods.

The validation of claw health records shows a large variation in how Danish claw trimmers record lesions, as other studies before us have established. There is a need for standardization in the recording practices between claw trimmers, to increase the usability of the data for the local farmer, the national breeding program, and international research. A solution may be national breeding societies demanding farmers to request claw health recordings by a trimmer certified by the authorities or breeding societies. This certification can be maintained by a yearly proficiency test. We are confident that farmers and veterinarians will realize the benefits of precise recordings, if they are recorded and applied correctly.

The validation of the trimming technique likewise exhibits a large difference in how and to what degree claw trimmers use the WLAM. A new generation of trimmers trained only in the WLAM is expected to comply more to the principles of the WLAM. We also found a difference between trimming the left and right leg for some trimmers, an issue without an apparent explanation.

The comparison between the two study periods show that WLAM is associated with reduced odds for SH, SU, WLF, and WLA. At the same time, it is associated with increased odds for DS. The same tendency is present when considering a homogenized and reduced population. When considering the results from the recording validation, the authors are reluctant in making conclusions concerning WLF and DS. Furthermore the cross-validation shows a large variance between the trimmers, which suggests an important interaction between the claw trimmer and the method.

By comparing the trimmers relative effect on the OR in the cross-validation to the trimmer's compliance to the WLAM, this study finds a tendency that a high level of compliance is associated with a larger effect of the WLAM. To understand and comply to the WLAM is crucial to achieve the full potential effect of the method. A large scale cohort study across several herds and years could determine the causal relationship between WLAM and a reduced prevalence of CHDL's.

The findings in this study indicate that the Danish claw trimmers could reduce the prevalence of SH, SU, and WLA by adapting and complying to the White Line Atlas Method.

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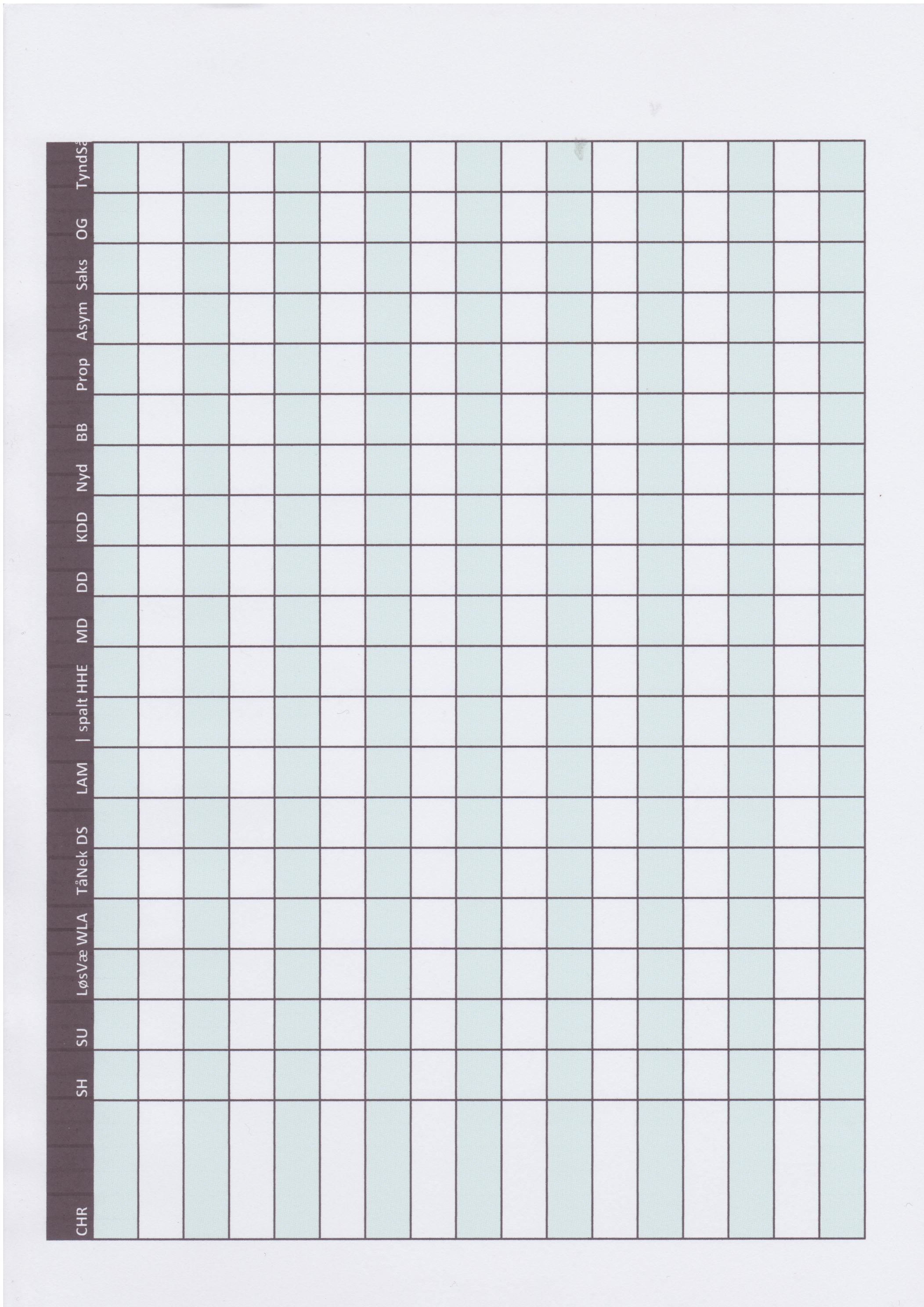
6 Appendix

Appendix A - Recording validation chart



Recording validation chart - each square has room for 4 dots representing each leg

Appendix B - Trimming validation chart

Ko nr.	Halthed	Over-rulnings-punkt	Dragt-højde	Såleflade	Balance	Om-drejnings-punkt	Axial hornvæg

Trimming validation chart - dichotomous values assigned to each hind leg

Appendix C - Model results

Sole hemorrhage

```
Generalized linear mixed model fit by maximum likelihood (Laplace
  Approximation) [glmerMod]
 Family: binomial  ( logit )
Formula: nSH/trimmings ~ method + (1 | klovbeskærings.chrnr)
   Data: analyse
Weights: trimmings

     AIC       BIC    logLik  deviance  df.resid
 40074.2   40097.4  -20034.1   40068.2     17222

Scaled residuals:
    Min       1Q   Median       3Q      Max
-9.1788  -0.8301   0.0584   0.8167   4.6484

Random effects:
 Groups                Name        Variance Std.Dev.
 klovbeskærings.chrnr (Intercept) 2.863    1.692
Number of obs: 17225, groups:  klovbeskærings.chrnr, 29

Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  0.36245    0.31373   1.155    0.248
methodWLAM  -0.13145    0.01885  -6.974 3.08e-12 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
           (Intr)
methodWLAM -0.031
```

Sole Ulcer

```
Generalized linear mixed model fit by maximum likelihood (Laplace
  Approximation) [glmerMod]
 Family: binomial  ( logit )
Formula: nSU/trimmings ~ method + (1 | klovbeskærings.chrnr)
   Data: analyse_SU
Weights: trimmings

     AIC       BIC    logLik  deviance  df.resid
```

```
   637.1     643.3    -315.5     631.1        55

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.7136 -1.1090 -0.0334  0.9830  5.2341

Random effects:
 Groups                Name        Variance Std.Dev.
 klovbeskærings.chrnr (Intercept) 0.6515   0.8071
Number of obs: 58, groups:  klovbeskærings.chrnr, 29

Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -2.74069    0.15301 -17.912  < 2e-16 ***
methodWLAM  -0.14460    0.03225  -4.484 7.33e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
           (Intr)
methodWLAM -0.103
```

White Line fissure

```
Generalized linear mixed model fit by maximum likelihood (Laplace
  Approximation) [glmerMod]
 Family: binomial  ( logit )
Formula: nWLF/trimmings ~ method + (1 | klovbeskærings.chrnr)
   Data: analyse_WLF
Weights: trimmings

     AIC       BIC    logLik deviance df.resid
   759.7     765.9    -376.8    753.7       55

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.9349 -1.5050 -0.0337  1.5085  3.7549

Random effects:
 Groups                Name        Variance Std.Dev.
 klovbeskærings.chrnr (Intercept) 0.5131   0.7163
Number of obs: 58, groups:  klovbeskærings.chrnr, 29

Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
```

```
(Intercept) -1.63015    0.13439 -12.130   <2e-16 ***
methodWLAM  -0.22976    0.02331  -9.855   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
           (Intr)
methodWLAM -0.084
```

White Line abscess

```
Generalized linear mixed model fit by maximum likelihood (Laplace
  Approximation) [glmerMod]
 Family: binomial  ( logit )
Formula: nWLA/trimmings ~ method + (1 | klovbeskærings.chrnr)
   Data: analyse_WLA
Weights: trimmings

     AIC      BIC   logLik deviance df.resid
   515.6    521.8   -254.8    509.6       55

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.3854 -0.8548 -0.1104  0.4518  3.5284

Random effects:
 Groups               Name        Variance Std.Dev.
 klovbeskærings.chrnr (Intercept) 1.071    1.035
Number of obs: 58, groups:  klovbeskærings.chrnr, 29

Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -3.62196    0.19982 -18.127  < 2e-16 ***
methodWLAM  -0.20155    0.04488  -4.491 7.08e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
           (Intr)
methodWLAM -0.106
```

Double sole

```
Generalized linear mixed model fit by maximum likelihood (Laplace
```

```
  Approximation) [glmerMod]
 Family: binomial ( logit )
Formula: nDS/trimmings ~ method + (1 | klovbeskærings.chrnr)
   Data: analyse_DS
Weights: trimmings

     AIC      BIC   logLik deviance df.resid
   720.7    726.9   -357.4    714.7       55

Scaled residuals:
    Min      1Q  Median      3Q     Max
-5.9640 -1.3292 -0.1749  1.3408  5.4513

Random effects:
 Groups               Name        Variance Std.Dev.
 klovbeskærings.chrnr (Intercept) 0.8125   0.9014
Number of obs: 58, groups:  klovbeskærings.chrnr, 29

Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  -2.7601     0.1702 -16.217  < 2e-16 ***
methodWLAM    0.1283     0.0301   4.263 2.01e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
           (Intr)
methodWLAM -0.097
```